

# Los Alamos

Los Alamos National Laboratory  
Los Alamos, New Mexico 87545

## memorandum

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EES-1

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### **QUALITY REPORT - ER AERIAL SURVEY AND RESULTANT ORTHOPHOTO AND DIGITAL CONTOUR DATA**

#### RELEVANT DOCUMENTS:

10-SEP-93, "Quality Inspection of Horizontal Accuracy of the Orthophotography", FAX to LANL, from Merrick and Company, Denver, Colorado.

23-SEP-91, "Increase in Services and Cost Ceiling for Task Order ME-158, P.I. #12169, Subcontract C-XP9-0942K- I", MEMO to Bryan Comer, Task Administrator, from Greg Cole, Project Leader, FIMAD.

08-OCT-91, "Final Survey Report for Los Alamos Mapping GPS Survey", REPORT to Merrick and Company from Hunsaker & Associates, San Benadino, California.

10-APR-92, "Fully Analytical Aerotriangulation Report", REPORT to Greg Cole, from Merrick and Company (GIS Mapping Services).

JUL-93, "Lab Wide Ground Survey - Phases I & II, Los Alamos, New Mexico", REPORT prepared through Molzen-Corbin and Associates, Inc., for Greg Cole from GEONEX, Denver, Colorado.

#### SUMMARY:

A two-part, GPS (Global Positioning System) survey was conducted in September, 1992 and June, 1993 to check the quality of products from an aerial survey performed by Merrick and Company and their subcontractor, Photosciences, Inc., for the Environmental Restoration (ER) Program at Los Alamos National Laboratory (LANL). Products from the aerial survey included orthophotos and digital contour data. The accuracy of horizontal locations on the orthophotos and elevations from the contour data were checked through GPS measurements at 64 well-defined sites.

No systematic errors in either the orthophoto or contour data were noted. The quality of positional determinations at the control sites is close to National Map Accuracy Standards and provide a 90% confidence (level) that horizontal errors are less than 2.1 feet and that vertical errors are less than 1.3 feet for data collected at the 1" = 100' mapping scale.

#### BACKGROUND:

The project to perform the aerial survey was initiated in early 1991 by the FIMAD on behalf of the ER Program. The purpose of this survey was to:

- fill in gaps in the existing 2' contour data coverage to meet EPA requirements,
- obtain a broad baseline to assess the quality of existing digital GIS (Geographic Information Systems) data, and
- provide photographic coverage which could assist in fieldwork and in identification of hazardous waste sites and environmental data types.

The work was performed through an existing A&E contract in place between LANL (Engineering Division) and Merrick and Company. Administrative details for the project were handled by ENG-2 and the FIMAD; technical details (with the exception of the initial ground survey) were the responsibility of the FIMAD. The aerial data were collected in late September, 1991; resultant orthophoto and contour data were created from the flight data in the ensuing two years.

#### DATA QUALITY REQUIREMENTS:

National Map Accuracy Standards (NMAS) for horizontal positions require that 90% of the "well-defined" data have positional errors of less than 1/50th of an inch at the final map scale. The ER survey requirements document specified final map scales of 1" = 100' for the region including the Laboratory and townsite (Los Alamos and White Rock), and 1" = 400' for the remainder of Los Alamos County including Bandelier National Monument. These map scales equate to 90% confidence levels of horizontal accuracy equal to  $\pm 2$  feet and  $\pm 8$  feet, respectively. The vertical errors are specified as less than 1/2 the contour interval for 90% of the "well-defined" data. Contour data were provided at 2-foot increments for 1" = 100' map sheets, and at 10-foot increments for the 1" = 400' map sheets; so that the 90% confidence levels of vertical accuracy equate to  $\pm$  foot and  $\pm 5$  feet, respectively.

Initial discussion with Photosciences Inc., the subcontractor responsible for the orthophoto data, indicated that the accuracy of the orthophotos would be less than that defined by the NMAS, with positional error bounds of 1/40th of an inch in sheet centers, and 1/30th of an inch at sheet edges. The lower accuracy was ascribed to optical/mechanical constraints aggravated by rapid slope changes common to the mesa/canyon topography prevalent in the Los Alamos area.

While the Task Order/Subcontract specifies conformance with the NMAS (see document of 23-Sep-91), the requirements were relaxed slightly due to the extreme topography of the survey area. The subcontractor agreed to make a good-faith effort to come as close as possible to meeting the NMAS for most portions of the survey area, especially within the Laboratory boundaries.

#### DESCRIPTION OF DATA QUALITY ANALYSIS:

A GPS survey was conducted by GEONEX of Denver to allow assessment of the data quality of the aerial survey. Well-defined control points were identified on orthophoto sheets by Greg Cole and Bob Greene of the FIMAD. GPS coordinates of these control points were obtained by GEONEX field crews at sufficient accuracy to meet NGS (National Geodetic Standards), 2nd order, Class 1 specifications (accuracy of 1 part in 50,000). Analysis of the results of the GPS survey indicates that horizontal accuracy of the control points is about 1 foot, and vertical accuracy is about .2 feet. Considerations in the placement of control points included:

- their ease of identification on both the orthophotos, and on the ground,
- their accessibility to uncleared personnel,
- their location in an area where the GPS equipment could adequately communicate with the satellite network,
- their distance from the initial GPS control points of the aerial survey,
- the availability of the orthophoto and contour data,
- the need to sample a variety of elevations, and locations separated by large elevation differences, and
- the need to test sheets of both final mapping scales.

Greg Cole and Bob Greene accompanied GEONEX personnel in the field to insure proper placement of the GPS stations.

The set of orthophotos consists of 428 sheets: 357 sheets at a scale of 1" = 100', and 71 sheets at a scale of 1" = 400'. The data quality survey consisted of 64 QA/QC locations, which sampled the accuracy of approximately 60 sheets (15% of the total sheets). The locations of the QA/QC sites are shown on the two maps attached to this memo. The survey report (document of Jul-93) provides details of the survey as well as digital coordinates of the QA/QC locations. In many cases, the actual GPS measurement site was offset from the QA/QC site to facilitate the measurement (i.e. if the QA/QC site was defined as the center of a telephone pole which was easily recognized in the orthophotos). Final coordinates of the QA/QC sites incorporate an adjustment for any offset.

Initially, orthophoto coordinates for the QA/QC sites were obtained through digitizing, using ARC/Info software and a Calcomp 9100-Series digitizer. Three individuals each digitized the set of 34 sites from Part 1 of the GPS survey. Excellent precision of co-location of points was obtained, with map differences of about a foot for repeated locations. Orthophoto coordinates showed a systematic shift of about 2' East and 3' South relative to the GPS coordinates. When Merrick and Company was unable to confirm this shift in their data, the accuracy of the digitizer was tested through the creation of a test grid by an electrostatic plotter with 1/400th of an inch resolution. This testing indicated that the quoted accuracy of the digitizer was suspect, and that positional errors due to this hardware sometimes exceeded 1/50th of an inch (2 feet at map scale).

The comparison of orthophoto and GPS coordinates was therefore done through creation of a set of mylar overlays to the orthophotos. These overlays contained locations of GPS sites, contour data, and other data. Offsets between the location of the QA/QC sites on the orthophotos and mylars were carefully measured under a magnifying lamp, and tabulated. Due to the coarseness of the registration marks on the orthophotos, and irregular distortion of the photographic media (paper), co-registration of the two media (photo and mylar) is considered accurate to 0.5 feet at best. For this reason, offsets were estimated to the nearest 0.5 feet. Aerial survey elevations for the GPS sites were interpolated from adjacent contour lines on the mylar overlays.

#### RESULTS OF DATA QUALITY ANALYSIS:

Misfits between the orthophoto and GPS coordinates are tabulated in the accompanying tables (Tables 1, and 2). For the 1" = 100'-scale orthophotos, the accuracy of the measurement of misfit is considered to range between 0.5 and 1.0 feet. The average horizontal error is about 1.7 feet (based on 56 sites). Assuming a normal distribution of errors for the measured misfit, the 90% confidence level for accuracy of locations on the orthophotos is  $\pm 2.1$  feet which is very close to the NMAS, and could certainly be considered equivalent given the uncertainties of the measurements of misfit and the accuracy of the control points. The 90% confidence level for accuracy of contour elevations is 1.3 feet, missing the 1-foot requirement by 30%. A good portion of this additional (4") error can be attributed to uncertainties in the horizontal position of the contours, localized variations in the topography, and the linear interpolation technique.

The 90% confidence level for accuracy of locations on the 1" = 400'-scale orthophotos is 9.9 feet (based on 9 sites), missing the 8-foot requirement by 25%. The 90% confidence level for elevation accuracy for this scale of mapping is 6.8 feet, which misses the 5.0 feet specification by 35%. Due to the limited number of samples, and the fact that some of the sites are not "well defined" due to extreme topography or heavy vegetation, the misfit error is not considered significant.

#### OTHER NOTES ON DATA QUALITY:

Users of data from this aerial survey must remember that the quality measurements are based on a sample of only 15% of the data. While the results of the quality survey are considered representative of the aerial data as a whole, local variations, can be expected. Where highly accurate, absolute positioning is required, GPS-based ground control should be used either for direct measurements, or for local registration of orthophoto images.

Users of topographic data from the aerial survey need to review the associated orthophotos to adequately determine potential quality problems in areas of extreme topography. Topography for areas of the orthophotos which are obscured by shadows, cultural structures, or landforms is generally "gu"estimated by linear interpolation. Thus, depending on the flight camera angle and the direction of shadows, cliffs may be interpreted as (steep) linear slopes, and interpolated contour elevations at their bases may therefore be in error by tens to hundreds of feet.

One other error was noted in the contour data during the course of the QA/QC survey. The presence of Los Alamos reservoir was not recognized so that the contours of that locality are in error.

#### CONCLUSIONS AND RECOMMENDATIONS:

The overall quality of the 1" = 100' orthophoto data can be considered to meet National Map Accuracy Standards. Absolute elevation data did not meet the accuracy requirements, with the 90% confidence limits being about 30% larger than specified. The vertical error can be due mostly to the horizontal uncertainties, does not impact the quality of the contour data, and is not significant in terms of the goals of the aerial survey. The quality of the 1" = 400' orthophoto data is slightly lower, probably due to the extreme topography, but still meets the needs of the ER Program.

Merrick and Company has met all the terms of the contract and should receive final payment for this project (C-XP9-0942K- 1, Task 158) in FY 93. They will retain custody of aerial photo and orthophoto negatives until the "Reproduction Services" contract (C-XP2-2092M-1, Task 008) is completed.

## CREDITS:

Bob Greene assisted in the location of QA/QC sites. Marcia Jones and Doug Walther digitized QA/QC site locations on the orthophotos. Liz Zeiler created the maps with GPS site locations, and the mylar overlays.

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Table 1. Summary of Orthophoto Location Errors for n= 100, Scale  
(Based on Geonix QA/QC GPS Survey )

Survey Point	GEONEX DATA NAD 83 Coordinates NGVD 29			DIFFERENCES ( MERRICK - GEONEX Orthophotos Contours				
	East	North	Elev.	ΔEast	ΔNorth	XY	Elev.	ΔElev
G93-0001	1636399.1	1742673.5	6353.4	-3.0	+1.0	3.2	6352.8	-.6
G93-0002	1632879.9	1744930.8	6653.4	0.0	-1.0	1.0	6653.1	-.3
G93-0003	1630172.1	1747171.4	6829.9	-1.0	+1.0	1.4	6829.3	-.6
G93-0004	1624883.9	1751125.8	7064.0	0.0	0.0	0.0	7063.7	-.3
G93-0005	1620477.4	1755679.7	7247.7	0.0	0.0	0.0	7247.6	-.1
G93-0006	1615453.4	1757364.5	7407.0	-1.0	+2.0	2.2	7407.5	+.5
G93-0007	1610814.6	1758730.8	7560.4	0.0	0.0	0.0	7560.3	-.1
G93-0008	1609964.9	1767182.1	7648.9	0.0	0.0	0.0	7650.0	+1.1
G93-0009	1610203.9	1770980.6	7761.6	0.0	0.0	0.0	7762.5	+.9
G93-0010	1612483.8	1773885.7	7757.0	0.0	0.0	0.0	7759.5	+2.5
G93-0011	1617759.0	1772956.4	7433.9	0.0	0.0	0.0	7433.9	0.0
G93-0012	1622458.5	1770413.2	7343.0	0.0	0.0	0.0	7343.0	0.0
G93-0013	1627274.3	1767406.2	7188.1	-1.0	+2.0	2.2	7188.3	+.2
G93-0014	1631314.1	1765234.6	7085.6	+1.0	0.0	1.0	7085.3	-.3
G93-0015	1635297.1	1763056.2	6930.6	0.0	+2.0	2.0	6930.3	-.3
G93-0016	1637716.1	1759899.7	6695.5	0.0	+1.0	1.0	6695.0	-.5
G93-0017	1620649.0	1774869.0	7331.4	+0.5	-1.0	1.1	7331.8	+.4
G93-0018	1624830.0	1773523.0	7307.2	0.0	0.0	0.0	7307.8	+.6
G93-0019	1631221.8	1771888.2	6960.7	-1.0	+2.0	2.2	6959.0	-1.7
G93-0020	1635867.3	1770491.6	6767.4	-1.0	+1.0	1.4	6767.0	-.4
G93-0021	1631486.4	1774761.5	7167.4	0.0	0.0	0.0	7167.2	-.2
G93-0022	1637203.5	1774772.7	7080.1	0.0	0.0	0.0	7079.3	-.8
G93-0023	1640705.9	1773897.4	6939.9	0.0	0.0	0.0	6940.6	+.7
G93-0024	1626838.8	1777826.1	7281.6	0.0	0.0	0.0	7282.0	+.4
G93-0025	1617301.4	1777077.1	7392.4	0.0	-1.0	1.0	7393.4	+1.0
G93-0026	1618295.4	1775717.6	7184.5	-1.0	0.0	1.0	7184.4	-.1
G93-0027	1623661.1	1778464.8	7210.4	0.0	0.0	0.0	7210.4	0.0
G93-0028	1633333.8	1778646.8	7099.4	0.0	0.0	0.0	7100.0	+.6
G93-0029	1618241.2	1781816.7	7415.0	0.0	0.0	0.0	7416.1	+1.1
G93-0030	1626539.7	1780142.4	7361.1	+0.5	-0.5	0.7	7362.2	+1.1
G93-0031	1630487.3	1783504.2	7273.2	0.0	0.0	0.0	7272.8	-.4
G93-0032	1621210.2	1784555.1	7393.7	-0.5	0.0	0.5	7394.6	+.9
G93-0033	1626629.7	1784806.6	7380.5	0.0	0.0	0.0	7381.0	+.5
G93-0034	1632396.2	1786271.7	6964.6	0.0	-1.5	1.5	6963.8	-.8
G93-0503	1640946.5	1769303.3	6663.1	0.0	+2.0	2.0	6662.3	-.8
G93-0504	1642382.7	1769383.3	6618.8	0.0	0.0	0.0	6618.6	-.2
G93-0505	1645121.1	1767721.9	6553.2	-2.0	+1.0	2.2	6552.2	-1.0
G93-0507	1649912.4	1747754.0	6455.5	0.0	+3.0	3.0	6454.2	-1.3
G93-0508	1653219.0	1745681.7	6328.1	+1.0	+1.5	1.8	6328.7	+.6
G93-0509	1657539.9	1754297.7	6304.7	0.0	+1.0	1.0	6304.4	-.3
G93-0510	1652467.1	1756695.8	6391.8	-1.0	+0.5	1.1	6391.7	-.1
G93-0511	1648829.4	1754731.7	6526.8	-0.5	+1.5	1.6	6525.1	-1.7
G93-0512	1646338.5	1755677.3	6554.0	+0.5	+1.0	1.1	6553.0	-1.0
G93-0514	1637029.1	1736621.1	6452.8	0.0	0.0	0.0	6452.6	-.2
G93-0515	1635770.3	1739048.7	6535.8	0.0	0.0	0.0	6534.0	-1.8
G93-0516	1652523.8	1771841.8	6296.9	0.0	0.0	0.0	6296.8	-.1

Table 1 (cont'd.)

G93-0521	1649325.6	1765166.1	6522.0	0.0	+2.0	2.0	6520.8	-1.2
G93-0523	1609651.7	1776846.9	7663.9	0.0	0.0	0.0	Not Available	
G93-0524	1609419.9	1763462.8	7662.1	-2.0	-1.0	2.2	7661.8	-.3
G93-0525	1646209.0	1736396.7	6399.0	0.0	0.0	0.0	6399.4	+.4
G93-0526	1639490.8	1736312.5	6428.9	+0.5'	+1.0	1.1	6428.5	-.4
G93-0527	1639559.9	1786779.3	6673.9	0.0	0.0	0.0	6673.8	-.1
G93-0528	1640005.2	1742132.8	6261.4	0.0	+1.5	1.5	6261.3	-.1
G93-0529	1643384.6	1776706.4	6528.1	0.0	0.0	0.0	6527.7	-.4
G93-0536	1606970.2	1760127.8	7752.2	-2.0	-2.0	2.8	7751.9	-.3
G93-0541	1661075.5	1756128.2	6232.3	0.0	0.0	0.0	6231.8	-.5

**Average** errors (in feet, Merrick orthophoto values - Geone GPS values)

East	-.2
North	+.4
Horizontal	1.7
Vertical	-.1

90% Confidence Limits (2 s.d.)

Horizontal	2.1
Vertical	1.3

Table 2. Summary of Orthophoto Location Errors for 1" = 400' Scale  
(Based on Geonix QA/QC GPS Survey)

Survey Point	GEONEX DATA			DIFFERENCES		MERRICK - GEONEX		
	NAD 83 Coordinates	NGVD 29		Orthophotos		Contours		
	East	North	Elev.	$\Delta$ East	$\Delta$ North	IXYI	Elev.	$\Delta$ Elev
G93-0523	1609651.7	1776846.9	7663.9	0	0	0.0	7655	-8.9
G93-0531	1599430.6	1758183.7	8399.2	0	0	0.0	8402	+2.8
G93-0532	1638181.0	1734978.0	6425.9	-10	+2	10.2	6426	+1.1
G93-0533	1635077.0	1737502.4	6052.2	-4	-10	10.8	6053	+1.8
G93-0534	1596812.3	1781856.8	9358.9	0	0	0.0	9362	+3.1
G93-0537	1668069.3	1776919.9	5626.5	-2	+1	2.2	5624	-2.5
G93-0538	1661957.0	1774108.9	5795.5	0	0	0.0	5792	-3.5
G93-0539	1635370.9	1803020.6	7088.0	-7	+4	8.1	Not Available	
G93-0540	1600840.1	1792796.7	9830.1	0	0	0.0	9833	+2.9

**Average errors** (in feet, Merrick orthophoto values - Geonex GPS values)

East	-2.6
North	-.3
Horizontal	6.9
Vertical	-.7

90% Confidence Limits (2 s.d.)

Horizontal	9.9
Vertical	6.8